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AN EXPLORATORY STUDY OF CONE MATURITY IN NOBLE FIR[1]

by

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Poor seed quality is often a problem in artificial regeneration of true firs (*Abies* sp.). Much true fir seed is sterile or blighted, and viability of sound seed is highly variable. Broadcast seedings require large amounts of seed, and nursery yields of seedlings from a given quantity of seed are variable. Reasons suggested for this poor quality relate to pollination, maturation, collection, processing, and storage of cones and seed.

The relationship of yield of viable noble fir *(Abies procera)* seed to (1) time of cone collection, (2) treatment of cones after collection, and (3) specific gravity and moisture content of cones at the time of collection was explored in this study.

TECHNIQUE

The major portion of this study was conducted in 1961 with cones collected from five mature trees located near the summit of Marys Peak, a 4,097-foot mountain in the Oregon Coast Ranges. Cones on each tree were mapped and numbered, and treatments were assigned to individual cones at random. Cones with external indicators of insect infestation were not used. Collections took place at 2-week intervals beginning August 22 and ending October 3. Natural seedfall occurred between October 8 and 18. Four cones on each tree were wired to prevent shattering and were collected on October 31.

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On each date, except October 31, five groups of four cones were collected from each tree and treated respectively as follows:

1. Spread out to dry in a garage loft; seed extracted on October 13.
2. Packed in paper wadding and stored dry in boxes for 2 weeks before seed extraction.
3. Packed in paper wadding and stored dry in boxes for 6 weeks before seed extraction.
4. Packed in moist peat moss and stored in boxes for 2 weeks before seed extraction.
5. Packed in moist peat moss and stored in boxes for 6 weeks before seed extraction.

Treatment 1 will hereafter be referred to as the "standard" treatment, because it approximates commercial handling. In treatments 2 through 5, each box contained only the four cones from a single tree. Boxes were kept in a room with a constant temperature of 40° F. and 70-percent relative humidity.

On each collection date, an additional group of four cones from each tree was gathered for specific gravity and moisture content determinations. They were kept in closed plastic sacks during transport. Specific gravity was determined by a water immersion technique. Weight was measured to the nearest gram, volume to the nearest cubic centimeter.

Seed was extracted and dewinged by hand, then cleaned in a pneumatic separator to eliminate empty and aborted seeds. Constant checks insured that less than 5 percent of sound seed was lost. The Oregon State Seed Testing Laboratory tested germination of four 100-seed lots drawn randomly from each tree-treatment-collection date combination. Seeds were stratified for 4 weeks at 5° C. and then tested with light for 21 days at temperatures of 20° C. at night and 30° C. during the day. Only seeds germinating normally were included in the germination percentages.

A smaller experiment was carried out on noble fir cones collected at about a 4,000-foot elevation on Red Mountain, a 4,977-foot peak on the crest of the Cascade Range in southern Washington. Eight cones were collected from each of five trees on four collection dates (September 1, 11, and 20 and October 3). Half were used for specific gravity determinations; the remainder were stored in the loft only 2 weeks before seed extraction. Snow prevented gathering those cones that had been wired for collection after the time of natural seedfall. Noble fir seedfall in this area occurred between October 9 and 25 in 1961.

RESULTS

Germination

Seed from cones collected in late August and early September, more than 1 month prior to natural seedfall (October 8 through 18), showed surprisingly high germination percentages, considering the earliness of collection (table 1). Although there is a slight upward trend from the first to the last collection (fig. 1), a regression analysis failed to reveal a significant correlation between germination

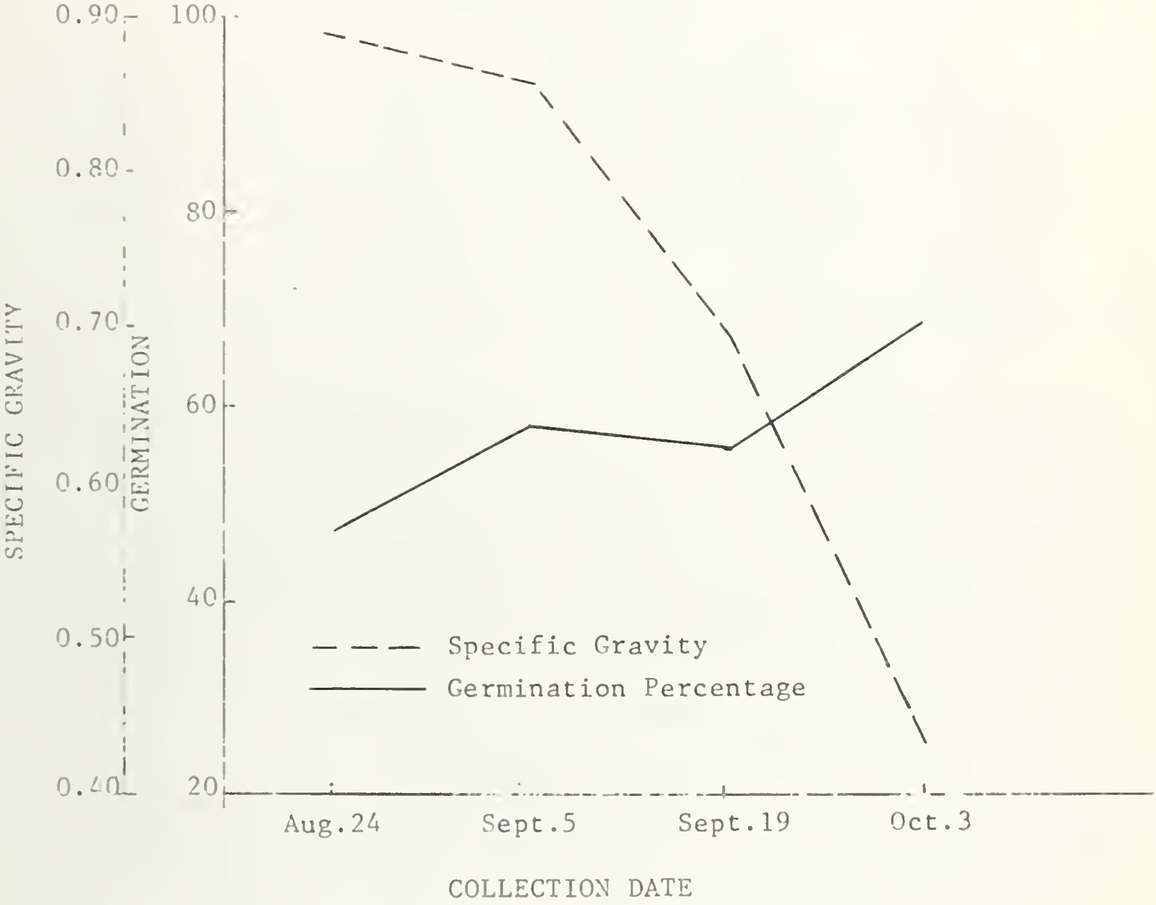

Figure 1.--Relation between specific gravity of freshly picked cones and germination percentages of seed extracted from cones receiving the standard treatment (Marys Peak collections).

Table 1.--Noble fir seed germination percentages by trees and collection dates, Marys Peak, Oreg., from cones given the standard treatment (each figure represents a mean of tests run on four 100-seed lots)

Tree	Collection date				
	Aug. 24	Sept. 5	Sept. 19	Oct. 3	Oct. 31
1	20.00	35.50	37.50	44.75	48.50
2	0	.75	31.50	4.25	27.00
3	62.50	80.50	73.00	79.00	68.75
4	63.00	75.50	59.50	72.75	68.25
5	42.00	42.25	48.50	78.50	60.00
Average (excluding tree 2)	46.85	58.40	54.65	68.65	61.20

percent and date of collection. However, an analysis of variance did indicate the existence of highly significant[2] differences in germination percentages between collection dates.

Seed from individual trees varied widely in maturity at different collection dates (table 1); the tree and collection date interaction in the analysis of variance was highly significant. Seed collected from trees 1 and 5 (prior to natural seedfall) showed a regular increase in germination as collection date advanced, whereas seed from trees 3 and 4 showed no general trend but fluctuated between 60- and 80-percent germination.

Large differences in viability of seed were found to exist between different trees, when comparisons were made of the highest germination values obtained from each (table 1). Of seed from the last collection date, germination percentages range from 27.00 to 68.75 percent, with three trees showing percentages above 60 percent.[3] Differences in germination percent between trees were highly significant.

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[2] In this note, "highly significant" is used in the statistical sense and means differences were shown to exist at the 1-percent level of probability. Analyses of variance on Marys Peak data were conducted twice--with and without the inclusion of data from tree 2--but the results of the tests were the same in all cases.

Results of Red Mountain germination tests were essentially the same as those of the Marys Peak tests (table 1) with a single exception. Germination percentages, averaged for all trees for each collection date, were 39.80, 43.50, 56.00, and 24.28, progressing from September 1 to October 3. Data from four of the five trees sampled showed this marked reduction in germination of seed from the last collection date. Differences in germination of Red Mountain seed (1) from individual trees, (2) on various collection dates, and (3) the interaction between trees and collection date were highly significant. Germination percent was not correlated with collection date, however.

The effects of the Marys Peak after-ripening treatments were generally deleterious (table 2). Dry storage was the least damaging with small differences between 2- and 6-week storage times. Moist storage was the most damaging, 6-week storage notably more so than 2-week storage. Differences in germination percent between after-ripening treatments were highly significant.

The analysis of variance indicated effects of after-ripening treatments varied with trees and with collection dates (highly significant interaction terms).

Specific Gravity and Moisture Content

As collection date advanced, specific gravity of freshly picked cones from Marys Peak declined steadily from a high of 0.89 on August 24 to 0.43 on October 3 (table 3). Regression analysis of specific gravity on collection date revealed a highly significant correlation

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[3] In the writer's opinion, cones from tree 2 were not comparable to those from the remaining trees. When the study trees were selected, cones on tree 2 appeared normal. Marked differences appeared at the time of the first collection, however, including: cones were of low specific gravity compared with the other trees; cones were spongy rather than hard or firm; seed was of very low quality, much of it empty or containing shriveled embryos; and cones had a high percentage of insect infestation. Furthermore, when placed in either dry or moist storage, cones from tree 2 developed an unusual mold for conifer cones, tentatively identified as *Cephalothecium roseum* by James W. Edgren of the Pacific Northwest Forest and Range Experiment Station.

Table 2.--Noble fir seed germination percentages, by after-ripening treatments of cones collected from Marys Peak, Oreg. (data from all trees, except tree 2, combined)

Treatment	Collection date				Average
	Aug. 24	Sept. 5	Sept. 19	Oct. 3	
Standard (loft storage until October 13)	46.85	58.40	54.65	68.65	57.14
Dry storage, 2 weeks	49.81	48.25	29.31	62.94	47.58
Dry storage, 6 weeks	36.25	47.81	30.81	54.38	42.31
Wet storage, 2 weeks	38.12	39.75	27.25	47.06	38.04
Wet storage, 6 weeks	24.38	22.44	25.50	47.00	29.83

Table 3.--Specific gravity of freshly picked noble fir cones collected on Marys Peak, Oreg., figures being average values for four cones

Tree	Collection date			
	Aug. 24	Sept. 5	Sept. 19	Oct. 3
1	0.90	0.88	0.65	0.43
2	.75	.82	.69	.51
3	.88	.84	.66	.49
4	.87	.86	.76	.42
5	.89	.86	.71	.39
Average (excluding tree 2)	.89	.86	.70	.43

(correlation coefficient r = 0.93), indicating most variability in specific gravity can be accounted for by collection date. Except for tree 2, there was relatively little tree-to-tree variation in specific gravity. The moisture content data had trends similar to those obtained for specific gravity. Specific gravity did not reflect fluctuations observed in germination percent (fig. 1), and regression analysis showed there was no correlation between germination percent and specific gravity.

Data for specific gravity and moisture content from the Red Mountain noble fir cones corroborated the results of the Marys Peak portion of the study.

DISCUSSION

Collection Date

Viability of noble fir seed collected in late August and early September was higher than expected. Cones collected from Marys Peak on August 24, 6 weeks prior to seed dissemination, produced seed that germinated nearly three-fourths as well as the seed collected on October 3. For the first three collections, the increase in germination as collection date advanced was more marked in the Red Mountain data.

An important reason for these results relates to the time span covered by the study. If collections had begun in July, a much greater increase in germination percentage of Marys Peak seed would undoubtedly have occurred, and a significant correlation between germination percent and collection date would be expected. For example, Pfister[4] studied maturity of grand fir seed beginning in late July 1961, and found a highly significant increase in germination with collection date. However, it is noteworthy that the germination percent of grand fir seed in Pfister's study continued to increase right up to the time of seed dispersal, whereas germinability of noble fir seed leveled off as time of dissemination approached.

A second important reason why a more dramatic increase in germination in relation to collection date did not occur may pertain to storage of the seed in cones following collection. Rediske and Nicholson[5] found noble fir seed required a maturation period in the cone following collection, during which there was a movement of organic substances from the cone into the seed. They felt seed maturity was associated with a calendar date and, therefore, the earlier cones were collected the longer seed would have to remain in the cone before it fully matured. This may be why seed collected from Marys Peak in August and early September had high viability. None was extracted from cones until October 13; seed was allowed to after-ripen in cones for periods proportional to the earliness of collection. The stronger upward trend of germination of seed from Red Mountain (for the first three collection dates) could be the partial result of processing these cones after only 2 weeks' storage so that the leveling effect of maturation in the cone was not realized.

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[4] Pfister, Robert Dean. Effects of artificial cone ripening techniques and determination of seed maturity in grand fir (*Abies grandis* Lindl.). M.S. thesis on file Oreg. State Univ., 48 pp., illus. 1964.

[5] Rediske, J. H., and Nicholson, David C. Maturation of noble fir seed--a biochemical study. 14 pp. 1962. (Submitted for publication as a Weyerhaeuser Forestry Paper.)

The depression in germination of seed obtained from Marys Peak trees 3 and 4 on September 19 or the major reduction in germinability of seed collected on Red Mountain at the last collection cannot be explained from available data. These cones were handled in the same manner as the others. Pfister (see footnote 4) encountered a similar decrease in average germination in a late August collection of grand fir seed.

After-Ripening Treatments

Artificial ripening procedures have been found useful in improving germination of early collected Douglas-fir seed (Silen 1958).[6] Pfister (see footnote 4) studied the effects of a variety of after-ripening treatments on germination of grand fir seed and found all, except storage of cones in wet peat moss, improved germination. Rediske and Nicholson (see footnote 5) noted no adverse effects of noble fir cone storage in open 3-gallon cans left in the shade. However, the storage treatments used in this study obviously were not favorable to the maturation of noble fir seed during after-ripening.

The dry-storage treatments in this study would be expected to have resulted in germination the same as, or slightly better than, the loft-storage or standard treatment in which cones were exposed to temperature and humidity fluctuations. In fact, the germination was usually below, sometimes far below, that obtained in the standard treatment. This was evidently the result of mold, developing in some of the boxes as a result of constant environmental conditions and absence of air circulation. In many cases, insect-infested cones developed intensive mold which spread to other cones in the same box. Extensive mold, in combination with anerobic storage conditions, was probably also responsible for the even poorer germination of seed from cones stored in moist peat moss.

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[6] Names and dates in parentheses refer to Literature Cited, pp. 11-12.

After-ripening procedures for improving germination of early collected noble fir seed should be developed. Rediske and Nicholson (see footnote 5) feel that moisture is a requirement for after-ripening of noble fir seed in the cones and that drying out of cones for seed extraction is sufficient to stop the after-ripening process. Pfister (see footnote 4) found a shaded outdoor exclosure provided the best conditions for after-ripening grand fir cones. Ideal conditions will involve a balance between the moist situation favorable for after-ripening and the dryness needed to discourage fungal growth. In any case, cones should not be stored in tightly closed containers, which prevent air circulation, nor tightly packed during after-ripening. Insect-infested cones, which serve as foci for fungal infection, should be removed when possible.

Variation Between Trees

Variations between trees at different dates reflected differences between trees in both timing of seed maturation and viability of seed produced (table 1). On Marys Peak, cones on trees 4 and 5 were obviously more mature by August 24 than were cones on trees 1 and 3, as shown by the increase in germination percentages from later collections. Time of cone maturation commonly varies between trees in the same vicinity in many species (Ching 1960, Fowells 1949, Rediske and Nicholson (see footnote 5), and others).

Erratic germinative behavior of seed from Marys Peak tree 2 may have been related to self-pollination or poor coordination between the receptivity of the female strobili and pollen flight. The many shriveled embryos suggest the former; the many empty seed suggest the latter. Recent work by Mergen and Lester (1961) suggests irregularities in the division of reproductive cells (meiosis) might also have been operative in causing these defective seeds.

Although no quantitative data were taken, observations indicate infestation of cones by insects varied greatly from tree to tree. The high percentage of infested cones on Marys Peak tree 2 has already been noted. Cones on some trees, such as Marys Peak 3 and 4, escaped infestation almost entirely.

Specific Gravity

A survey of the literature reveals specific gravity is the most widely used measure of cone maturity. Specific gravity indices have been developed for a large number of pines (Eliason and Hill 1954, Fowells 1949, McLemore 1954, Maki 1940) and several spruces (Cram 1956, Cram and Worden 1957) and could be developed for Douglas-fir (Ching and Ching 1962). Pfister (see footnote 4) studied several different characteristics of grand fir seed and cones and concluded specific gravity was the best indicator of maturity. Other measures of cone maturity, such as color (Crossley 1953, Pfister (see footnote 4)) or characteristics of the seed embryo or endosperm (Pfister, footnote 4), have been less successful. Excellent indices of maturity, based upon biochemical analyses of extracted seed, have been developed for Douglas-fir (Rediske 1961) and noble fir (Rediske and Nicholson, footnote 5), but these require laboratory facilities and trained technicians.

In this study, specific gravity and moisture content show strong relationships to date of collection. Specific gravity and moisture content were not correlated with germination percent in this study, however, and failed to reflect fluctuations in germination encountered for individual trees or major anomalies such as the large reduction in germination occurring in the last Red Mountain collection. As mentioned earlier, failure to obtain a correlation is probably due to the late date at which collections were begun. The time span covered by the study was evidently beyond the period of rapid change for most trees. During the period of time represented, specific gravity was not a valid criterion for determining appropriate times for cone collection. However, since good germination was usually obtained from seed collected as early as late August, an index of cone maturity would have been of little importance in commercial collection over the time span covered by this study in 1962--the seed not having been extracted immediately after collection.

There was some indication that a specific gravity of about 0.90 is critical, however. The two trees showing the greatest percentage increase in germination after the first collection date--Marys Peak tree 1, 20.00 to 48.50 percent, and Red Mountain tree 2, 13.00 to 70.00 percent--had cones with specific gravities of 0.903 and 0.959, respectively, at the time of the first collection. The remaining trees had cones with specific gravities below 0.90 and did not show as marked an increase in germination for later collections. This specific gravity may indicate the earliest collection time possible if a reasonable percentage of the maximum potential germination of the seed is to be obtained, even when cones are stored for several weeks after collection. It is noteworthy that Pfister (footnote 4) tentatively suggested use of a specific gravity of 0.90 as an index for determining when collection of grand fir cones should begin.

Conclusion

This study indicates that early collection of noble fir cones, per se, is not necessarily the most important cause of poor seed germination. Poor germination may also result from the treatment of cones after collection and the extraction, cleaning, and storage of seed; or, more likely, from a cumulative effect of these factors, including early collection.

Much research needs to be done on maturity indices and seed quality for western true firs. The relationship between specific gravity and germination of noble fir seed should be studied beginning in late July and the proposed critical specific gravity of 0.90 carefully evaluated.

Other important true firs such as Pacific silver fir and subalpine fir should be studied. An adequate method of after-ripening cones needs to be developed.

SUMMARY

A study was made of the relationship of seed germination to date of collection, after-ripening treatment, and specific gravity of noble fir cones collected in the Oregon Coast Ranges and Washington Cascade Range. Noble fir seed, obtained from cones collected 6 weeks prior to natural seedfall and allowed to after-ripen in the cones, germinated about three-fourths as well as seed from later collections.

Both dry and moist after-ripening treatments of cones, carried out in this study, were generally deleterious in their effect on seed germination when compared with a standard treatment of open storage in a garage loft. Molding was a major problem.

Specific gravity and moisture content of freshly picked cones were closely related to time of collection but did not reflect fluctuations noted in seed germination. Lack of relation between specific gravity and seed germination is probably due to the late date at which collections were begun. However, it is tentatively recommended that cones not be collected until they have attained a specific gravity of 0.90.

Major differences existed in the highest germination values of seed obtained from different study trees. Furthermore, cones on different trees matured at different times and responded differently to the after-ripening treatments.

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